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SANITARY BACTERIOLOGY OF THE UPPER POTOMAC ESTUARY

Donald W. Lear, et al

Federal Water Pollution Control Administration
Annapolis, Maryland

March 1969

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Chesapeake Technical Support Laboratory
Middle Atlantic Region
Federal Water Pollution Control Administration
U.S. Department of the Interior

Technical Report No. 6

SANITARY BACTERIOLOGY OF THE UPPER POTOMAC ESTUARY

by

Donald W. Lear, Jr.
and
Norbert A. Jaworski

March 1969

Supporting Laboratory Staff:

Johan A. Aalto, Director
James W. Marks, Chief of Field Crew
Orterio Villa, Jr., Chemist
Robert L. Vallandingham, Boat Captain
Anna R. Favorite, Statistician
Rose Ann Tilton, Typist

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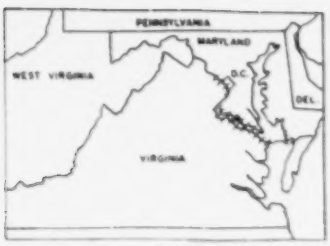
INTRODUCTION

As part of the Chesapeake Bay-Susquehanna River Basins Project, the Chesapeake Field Station undertook extensive field investigations to determine the water quality in the Potomac River Basin. A significant part of these studies was the determination of the bacteriological water quality condition of the upper Potomac Estuary.

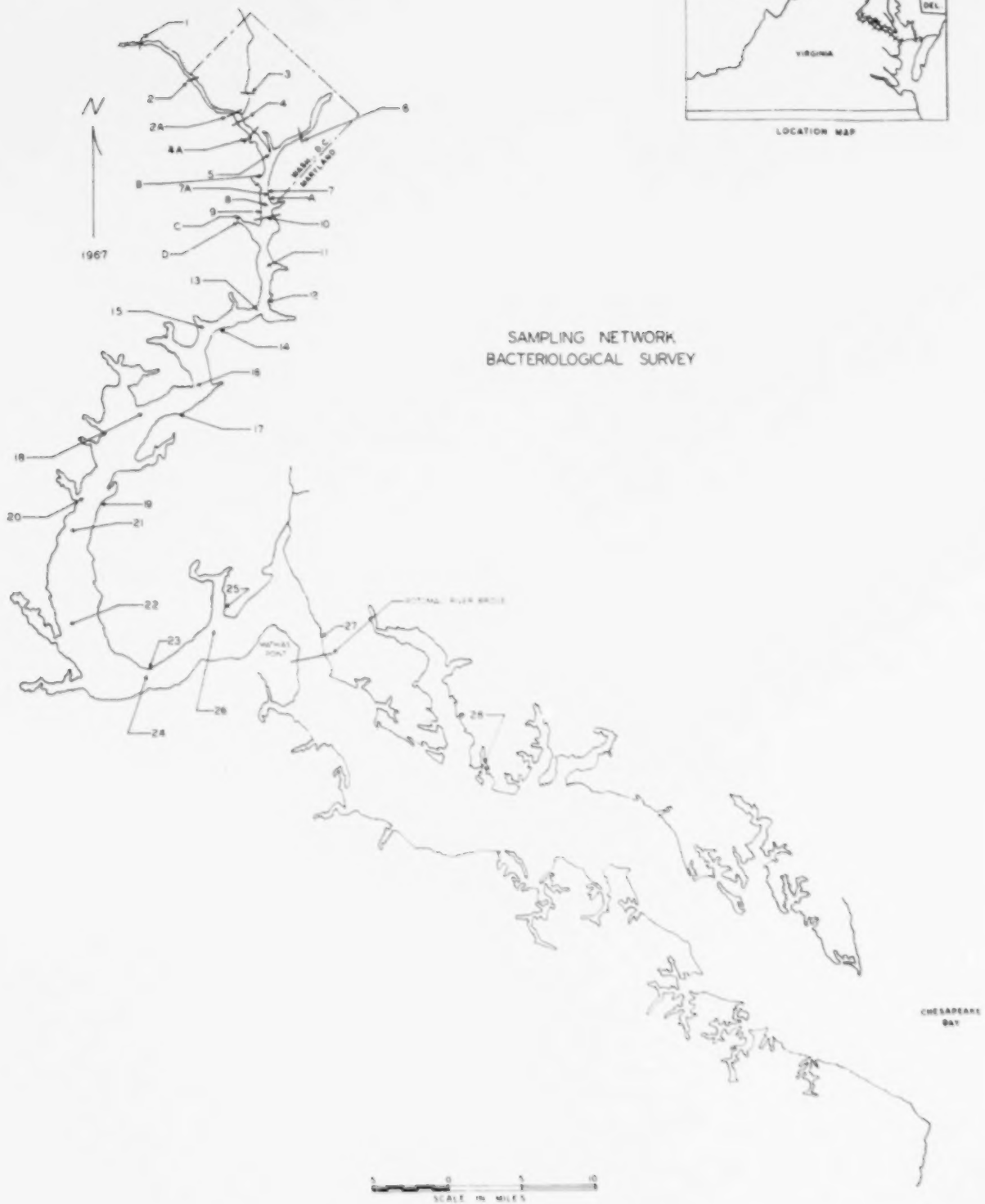
A study was initiated in winter 1967 to:

1. Determine the bacteriological water quality of the upper Potomac Estuary;
2. Relate bacterial distributions to other water quality parameters;
3. Evaluate an isolation procedure for Salmonellae;
4. Relate the comparative usefulness of coliforms, fecal coliforms, fecal streptococci and Salmonellae as water quality indicators;
5. Identify probable sources of bacterial pollution in the area.

The study area encompassed a reach of the estuary above the wastewater discharge in the Washington, D.C. metropolitan area to the oyster producing waters of the middle estuary below the Potomac River Bridge at Dahlgren, Virginia. (Figure 1)



LOCATION MAP



POTOMAC ESTUARY

FIGURE 1

STUDY PROCEDURES

Sampling Stations and Programs

A sampling network of 31 stations was established along 60 miles of the upper Potomac Estuary. Wastewater effluent samples were also obtained from the four major sewage treatment plants in the Washington metropolitan area. Figure 1 and Table 1 give detailed locations of the sampling stations and sewage treatment facilities.

Upstream bacteriological samples above navigable waters in the Washington area were taken from bridges, iced, and returned within three hours to the laboratory at Annapolis for inoculation and incubation. For the remaining estuary studies bacteriological samples were taken to the Chesapeake Field Station mobile camper laboratory located along the river in positions to receive samples directly from boat crews. Water samples were immediately inoculated into presumptive media and incubated aboard the camper. This procedure was instituted to minimize any bacteriological changes during the transport period.

Salmonellae were isolated by an immersed swab procedure [1]. Bundles of cheesecloth strips (swabs) were suspended from bridges or buoys at various points in the river. Where the swabs could not be suspended in midwater due to inaccessability, they were tied to stakes near shore in one foot lengths of four inch PVC pipe to minimize contact with bottom sediments. The swabs were usually immersed

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TABLE 1

Description of Sampling Network

Bacteriological Survey

Chesapeake Field Station
1967

Station No.	Description	Salmonella Samples	Coliform Samples
1	Cabin John Bridge	x	x
2	Chain Bridge	x	x
2A	Key Bridge		x
3	Rock Creek-M St. Bridge	x	x
4	Memorial Bridge	x	x
4A	14th St. Bridge		x
5	Haines Point	x	x
6	Anacostia River-S.Capitol St.Br.	x	x
7	Bolling AFB - Buoy 9	x	x
7A	Bellvue - 23 ft. bell		x
8	Blue Plains - Buoy 8	x	
9	Alexandria Marine Service Dock	x	
10	Woodrow Wilson Bridge	x	x
11	Broad Creek - Buoy 86	x	x
12	Fort Washington - Bank	x	
13	Fort Washington - Buoy 75	x	x
14	Marshall Hall - Dock	x	
15	Dogue Creek - Buoy 67	x	x
16	Hallowing Point - Buoy 61	x	x
17	Indian Head - Navy Dock	x	
18	Indian Head - Buoy 54	x	x
19	Moss Point - Bank	x	
20	Possum Point - Buoy 44	x	x
21	Sandy Point - Buoy 40	x	x
22	Smith Point - Buoy 30	x	x
23	Maryland Point - Bank	x	
24	Maryland Point - Buoy 19-21	x	x
25	Nanjemoy Creek - Dock	x	
26	Nanjemoy Creek - Buoy 11	x	x
27	Aqualand Seawall	x	
28	Cobb Island - Bank	x	
A	Blue Plains STP effluent	x	x
B	Arlington STP effluent	x	x
C	Alexandria STP effluent	x	x
D	Westgate STP effluent	x	x

for a period of five days; however, at times the duration ranged from four to seven days because of weather conditions controlling the installation and retrieval.

Disposable polyethylene gloves were used in the handling of swabs during retrieval. The swabs were placed in polyethylene bags, tightly secured, and iced for return to the laboratory at Annapolis for further processing. No attempt was made to pre-sterilize the swabs, gloves, or polyethylene bags. Control swabs, identical in handling except for immersion, were run in parallel and yielded uniformly negative results.

A departure from the swab technique was made for the isolation of Salmonellae from sewage treatment plant effluents. For the effluents, 150 ml of sample was passed through HA millipore filters*, with the filters processed similarily to the retrieved swabs.

Analytical Procedures

1. Indicator Bacteria (Coliform, Fecal Coliform and Fecal Streptococci)

The 5-tube, 4 dilution MPN technique was used. For presumptive coliforms and fecal coliforms Difco lauryl tryptose broth was employed; for presumptive fecal streptococci Difco azide dextrose broth was used. Incubation was at 35° C.

Coliforms were confirmed in Difco brilliant green bile 2% broth. Fecal streptococci were confirmed in Bacto ethyl violet azide broth. Fecal coliforms were confirmed in Bacto EC medium, incubated at 45.5° C. These procedures are outlined in detail in Standard Methods [2].

* HA millipore filter has an effective pore size of 0.45 microns

2. Salmonella

In the laboratory each swab was cut with alcohol-flamed scissors and approximately one-third of each swab was placed in 300 ml of tetrathionate enrichment broth. This was incubated at 40.5° C for twenty-four hours in a water-jacketed incubator. Subsequently, a sterile bacteriological loop was used to streak from the enrichment medium onto brilliant green agar plates and, in parallel, on SBG agar plates. These latter plates were abandoned after the first few attempts as this method did not yield enough presumptive Salmonella colonies to warrant further use in this study.

The brilliant green or the SBG agar plates were incubated at 40.5° C overnight and characteristic presumptive Salmonella colonies were fished with a sterile bacteriological needle and placed in parallel on triple sugar iron (TSI) agar slant stabs, motility sulfide (MS) agar stabs and inoculated into "H broth". The TSI slants were read between eight and eighteen hours. It was found that leaving this medium overnight resulted in a masking of the color reactions by excessive sulfide production, consequently shorter reading intervals were used. After noting slant, butt and sulfide reactions in the TSI tubes, a loopful of culture from the slant was used for a slide agglutination test with polyvalent Salmonella "O" antiserum.

In the motility and sulfide medium, reaction for motility and

sulfide was first noted, then the tubes flooded with buffered urea solution, incubated at 35° C for six hours to note the presence or absence of urease production. A portion of the culture in "H broth" was used to test for the presence or absence of indol. A further aliquot of "H broth" was used for a tube agglutination test with polyvalent Salmonella "H" antiserum.

After initially screening all cultures with this procedure, cultures were again purified on brilliant green agar and again subjected to this series of tests. Forty-one selected cultures isolated from the upper Potomac Estuary were sent to the U.S. Public Health Service Communicable Disease Center at Atlanta, Georgia, for further diagnosis to species serologically.

Details of the Salmonella isolation scheme are elaborated by Spino [1]. Strict adherence to details outlined by Spino is recommended, for this scheme is extremely empirical and small deviations can result in failure.

CLIMATOLOGICAL CONDITIONS

During the months of January and February 1967, the weather was generally cold and dry with the Potomac River discharge at approximately 10,000 cfs. A light rainstorm with above-freezing temperatures covered much of the Potomac watershed during the period from March 4 through 7. The rainstorm and thaw increased the runoff to a maximum discharge of 140,000 cfs on March 9, 1967. (See Figure 2)

The average climatological conditions for the three months of the study are given below.

Parameter	January	February	March
Air temperature (Deg. F°)	41.0	34.0	45.0
Water temperature (Deg. F°)	37.0	37.8	42.7
River discharge (cfs)	9,700	10,800	35,600
Precipitation (inches)	1.35	2.32	3.49

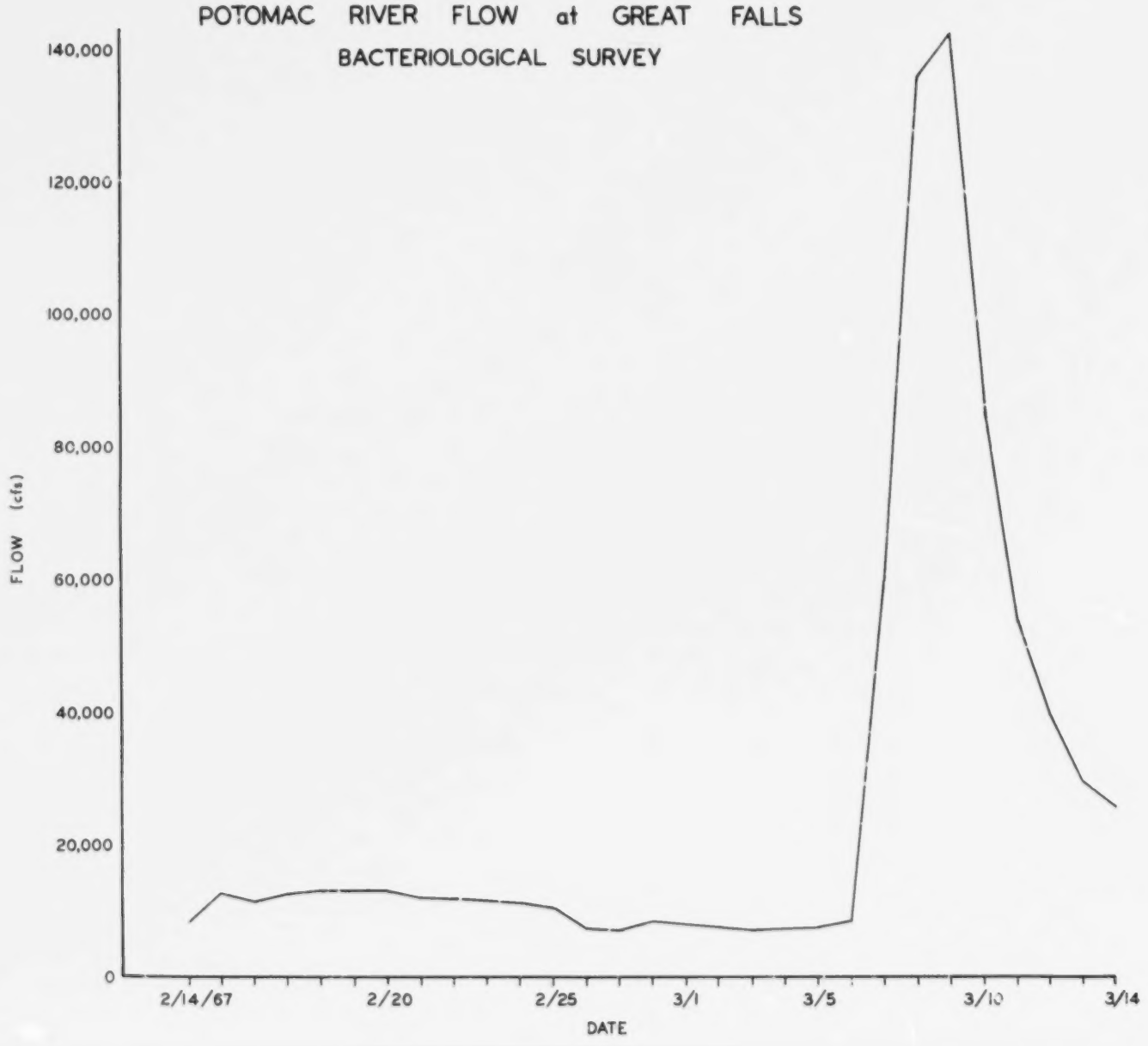
POTOMAC RIVER FLOW at GREAT FALLS
BACTERIOLOGICAL SURVEY
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
FLOW (cfs)
2/14/67
2/20
2/25
3/1
3/5
3/10
3/14
DATE

FIGURE 2

RESULTS OF STUDY

Sources of Coliform Organisms

Three major sources of coliform organisms in the upper estuary were: (1) wastewater discharges, (2) storm and combined sewers, and (3) fresh water inflows. Using the data for the sewage treatment effluents for the major discharges and fresh water inflow, an estimate of the coliform organism loadings for the months of February 1967, was determined and is presented below.

	Coliform (MPN/day)	Fecal Coliform (MPN/day)	Fecal Strep. (MPN/day)
Fresh water inflow*	0.12×10^{15}	0.04×10^{15}	0.08×10^{14}
Wastewater treatment discharge**	160.0×10^{15}	19.5×10^{15}	60.3×10^{14}

As can be seen in the above tabulation, the contribution of coliform organisms from wastewater effluents is more than 100-fold greater than from the fresh water inflow from the upper basin. No estimate was made of storm or combined sewer contributions.

* Based on an average flow for the month of February 1967 of 10,800 cfs.

** Based on the bacterial densities for Blue Plains, Arlington and Alexandria data as presented in Table 2.

Estuarine Water Quality Conditions

Figure 3 is an isopleth plot* of coliform distribution in the study area. The region of greatest coliform density (> 100,000 MPN/100 ml), with steady flow conditions of approximately 10,000 cfs, seemed to equilibrate in the reach from just below the District of Columbia downstream to Hallowing Point, approximately 15 miles of estuary. The sudden rise in fresh water flows carried these high coliform densities, with some small contribution from local land runoff as evidenced by the increased count at Chain Bridge, downstream at least 40 miles, the lower limit of this study.

This investigation did not include the estuary below Mathias Point which is the upper limit of the oyster harvesting areas. These waters would probably be affected by the increased flows which transport the indicator organisms apparently originating in the metropolitan area.

The fecal coliform densities (Figure 4) showed a similar response to the high flow conditions, but at a bacterial density approximately one decimal order of magnitude lower than coliforms. The reach of the estuary affected was identical.

Figure 5 presents the distribution of fecal streptococci in the upper Potomac Estuary. Distribution patterns were similar to

* An isopleth is made by plotting coliform densities as a function of time and distance, and connecting equal values. The response of the estuary to the coliform loadings can be seen at a given time by following distributions from a fixed point in time down the horizontal axis, representing the reach of estuary studied. Conversely, at a fixed point in the estuary, the changes of the densities with time can be seen by reading up a vertical axis from a designated location.

those for coliforms and fecal coliforms, but the area of high bacterial density was not as extensive, consonant with the concept that fecal streptococci have a relatively faster die-off rate in water than coliforms or fecal coliforms and are indicators of recent pollution. [3]

Figure 6 shows the exposure of Salmonella swabs and subsequent recovery or lack of recovery of Salmonella isolates. The area of greatest incidence included the metropolitan area downstream to Indian Head, Maryland. Somewhat surprising were the isolations from Chain Bridge, where generally low coliform and fecal coliform densities were found.

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COLIFORM DISTRIBUTION ISOPLETH

(MPN/100 ml)

UPPER POTOMAC ESTUARY

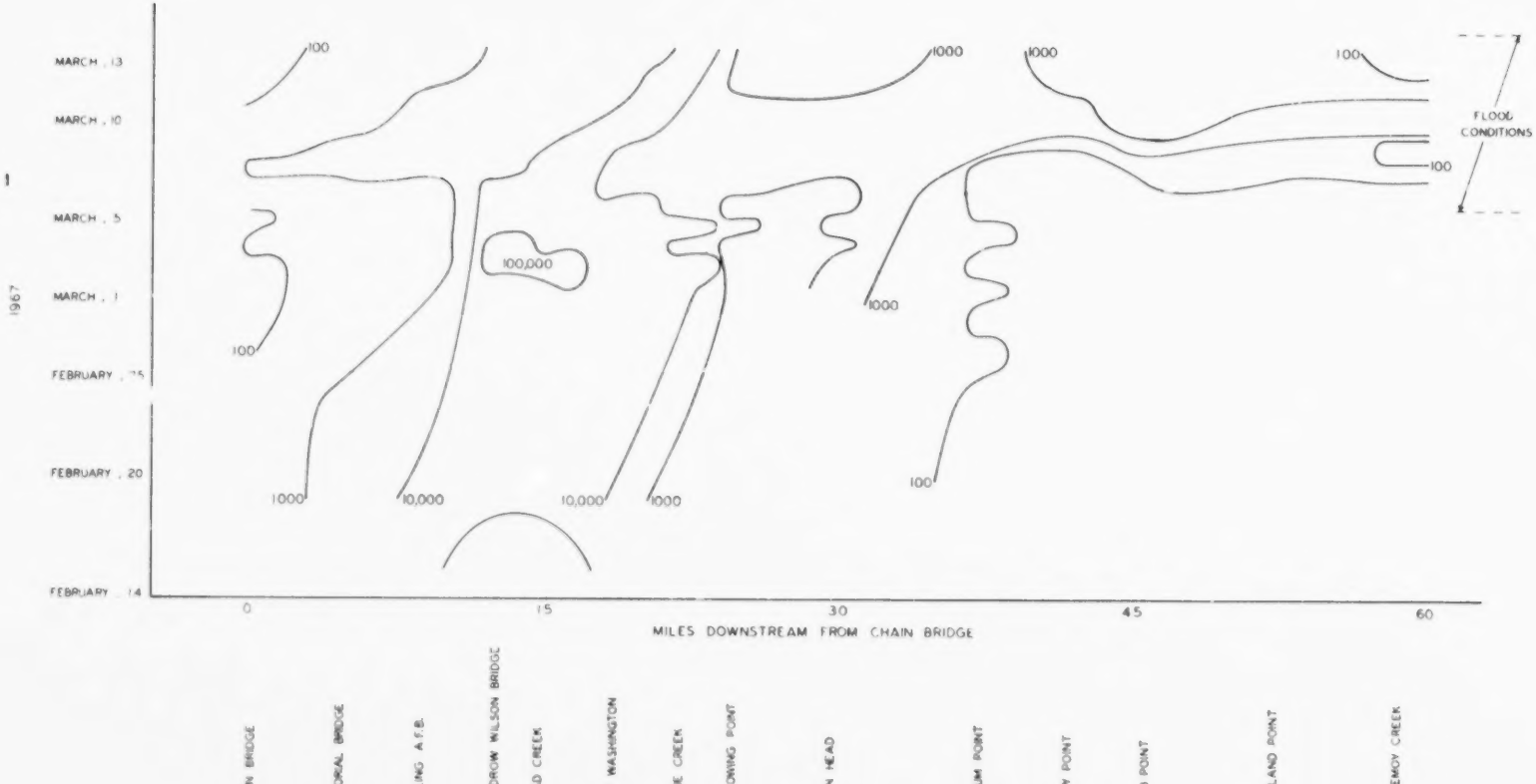
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

FECAL COLIFORM DISTRIBUTION ISOPLETH

(MPN/100 ml)

UPPER POTOMAC ESTUARY

CHESAPEAKE TECHNICAL SUPPORT LABORATORY

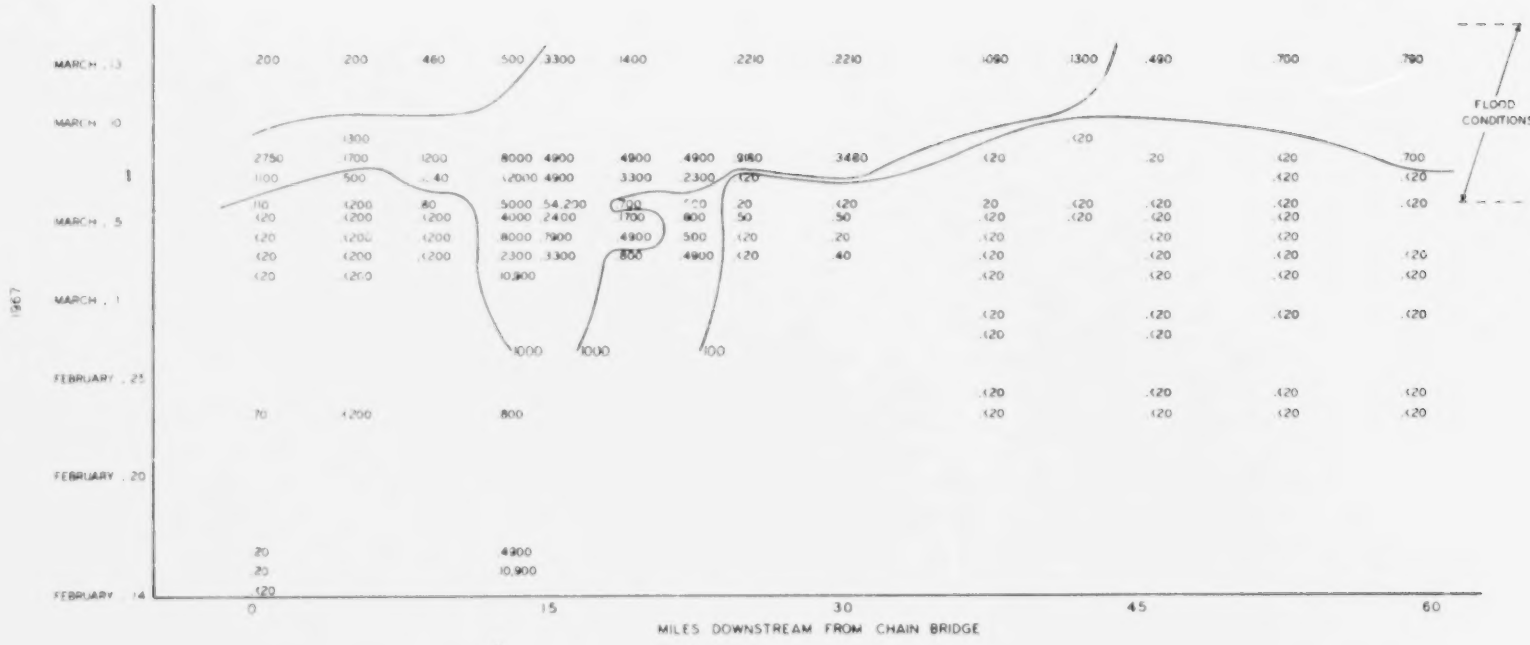


FECAL STREPTOCOCCI ISOPLETH

(MPN/100 ml)

UPPER POTOMAC ESTUARY

CHESAPEAKE TECHNICAL SUPPORT LABORATORY



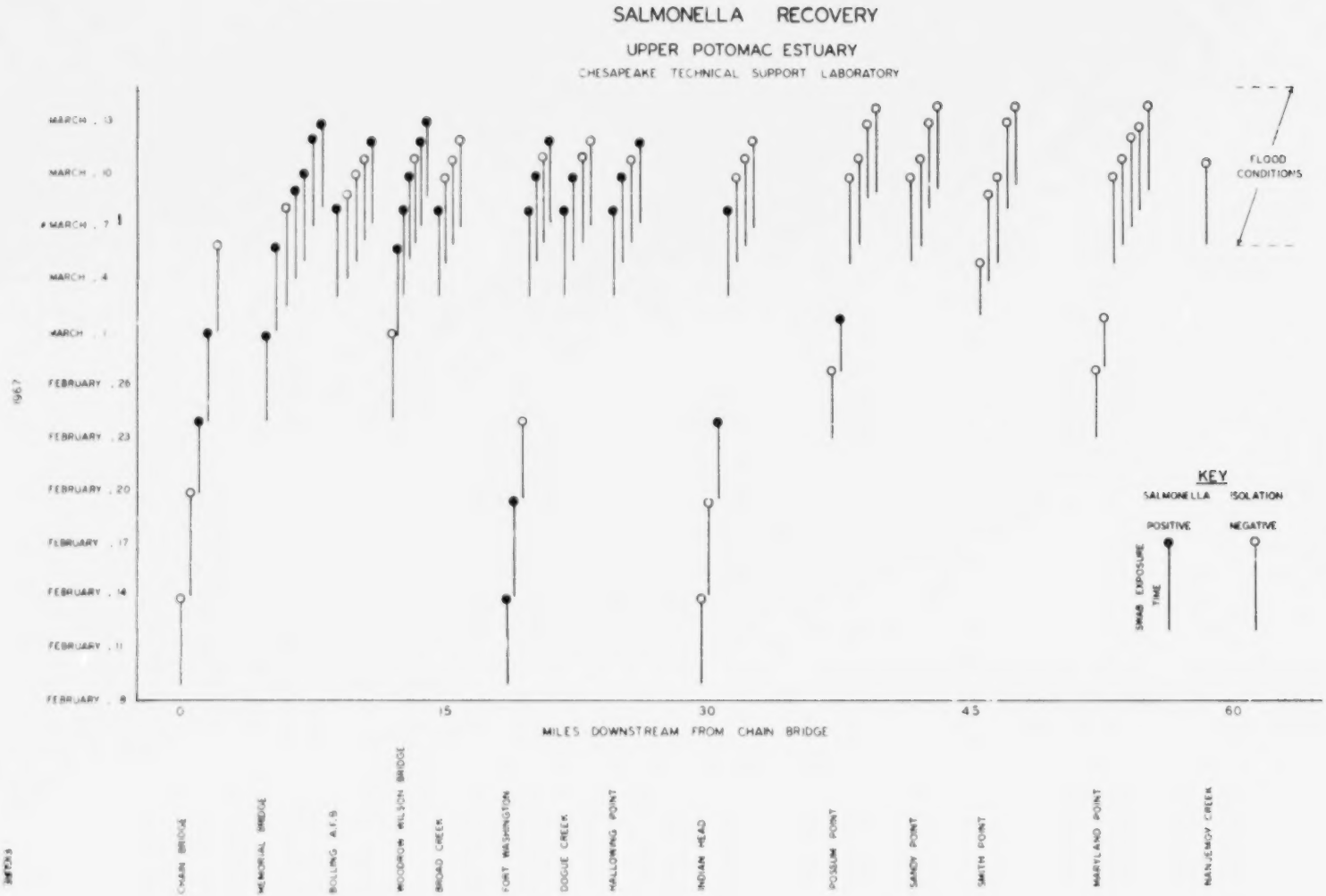

SALMONELLA RECOVERY
UPPER POTOMAC ESTUARY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY
1967
MARCH . 13
MARCH . 10
MARCH . 7
MARCH . 4
MARCH . 1
FEBRUARY . 26
FEBRUARY . 23
FEBRUARY . 20
FEBRUARY . 17
FEBRUARY . 14
FEBRUARY . 11
FEBRUARY . 8
FLOOD CONDITIONS
KEY
SALMONELLA ISOLATION
POSITIVE
NEGATIVE
SMAB EXPOSURE TIME
0
15
30
45
60
MILES DOWNSTREAM FROM CHAIN BRIDGE
CHAIN BRIDGE
MEMORIAL BRIDGE
BOLLING A.F.B.
WOODROW WILSON BRIDGE
BROAD CREEK
FORT WASHINGTON
DOGUE CREEK
HALLOWING POINT
INDIAN HEAD
POSSUM POINT
SANDY POINT
SMITH POINT
MARYLAND POINT
NANJEMOY CREEK

TABLE 2

SALMONELLAE AND INDICATOR-BACTERIAL DATA
UPPER POTOMAC ESTUARY
JANUARY - MARCH 1967
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Date Sample Set	Date Sent Retrieved	Date Sample Taken	Time Sample Taken	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Streptococci MPN/100 ml	Salmonella Recovery	Salmonella Serotype
					Station 1 - Cabin John Bridge				
1-	1-							-	
		1-1	1145	4	17,000	1,100	100		
		1-			,400	490	70		
		1-			50	20	20		
		1-14	1030		790	230	20		
		1-	1145						
					Station 2 - Chain Bridge				
		1-11	1130	4	7,180	1,300	80		
		1-			790	130	< 20		
1-	1-	1-14	1100		130	< 30	< 20	-	
		1-15	1145	4.5	330	170	20		
		1-16	1040	5.0	330	230	20		
								-	
1-14	1-	1-	1100		790	170	70		
								+	S. typhimurium
1-	1-4							+	S. montevideo
-	3-1								
		3-	0945	3	80	50	< 20		
		3-3	1015	3	90	20	< 20		
		3-			310	230	< 20		
		3-			330	50	< 20		
-	3-	3-	0930	5	3,480	790	110	-	
		3-	0920		9,180	790	1,100		
		3-8	0940	4.0	6,300	2,400	2,780		
		3-	0930	5	3,480	130			
		3-10	1000	7		1,090			
		3-11							
		3-1	0915	7					
		3-13	1000	8	1,200	80	200		
					Key Bridge - 3.3 miles from Station 2				
		1-14	0810		200	< 200	< 200		
		1-	1555	4	16,090	3,480	490		
		2-15	1155	4.5	1,300	490	20		
		2-16	1025	5	2,400	1,300	50		

TABLE 2 - continued

Date Swab Set	Date Swab Retrieved	Date Sample Taken	Time Sample Taken	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Streptococci MPN/100 ml	Salmonella Recovery	Salmonella Serotype
					Station 3 - Rock Creek, M Street Bridge				
2-14	2-20							+	S. eimsbuettel
		2-23	1125		500	500	< 200		
2-20	2-24							+	
-	3-01	3-01			-	-	-	+	
		3-02	1100	0	17,000	3,300	200		
		3-03	1100	2	1,609,000	3,300	900		
		3-04			141,000	14,000	2,000		
		3-05			55,000	5,000	4,000		
-	3-06	3-06	0950	6	330,000	26,000	7,000	+	
		3-07	0945	5.5	100,000	13,000	70,000		
		3-08	1020	3.5	23,000	23,000	2,000		
		3-09	1000	4	13,000	5,000	< 2,000		
3-05	3-10	3-10	1150	6		49,000		+	S. bredeney (027 neg)
		3-11							
		3-12	0945	8					
3-08	3-13	3-13	1020	6.5	11,000	< 2,000	23,000	-	
					Station 4 - Memorial Bridge				
1-20	1-24							+	S. cubana
		2-23	1125		12,000	9,000	7,900		
-	3-01	3-01			-	-	-	+	
		3-02	1100	0	200	< 200	< 200		
		3-03	1100	2	500	200	< 200		
		3-04			< 200	< 200	< 200		
		3-05			000	< 200	< 200		
-	3-06	3-06	1015	5	500	200	< 200	+	
		3-07	1500	4	34,500	800	500		
3-03	3-08	3-08	1040	4	24,000	3,300	1,700	-	
3-4	3-09	3-09	1015	5	4,600	1,300	1,300	+	
3-5	3-10	3-10	1120	6		800		+	
		3-11							
3-07	3-12	3-12	1000	8				+	
3-08	3-13	3-13	1045	8	11,000	400	200	+	S. muenchen
					14th Street Bridge - 5.7 miles from Station 2				
		1-24	0820		500	200	< 200		
		1-30	1530	3.5	16,090	2,400	700		
		2-15	1050		490	490	40		
		2-16	1005		9,180	2,210	140		
					Station 5 - Haines Point, Buoy 2				
1-11	1-12							+	S. thompson
1-11	1-16							-	
		1-24	0830		< 200	< 200	< 200		
		1-30	1515	4	34,800	2,400	3,480		

TABLE 2 - continued

Date Swab Set	Date Swab Retrieved	Date Sample Taken	Time Sample Taken	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Streptococci MPN/100 ml	Salmonella Recovery	Salmonella Serotype
					Station 6 - Anacostia River, Sousa Bridge				
		2-23	1400		34,800	5,420			
-	3-01	3-01			-	-	-	-	
		3-02	1330	3	4,900	2,300	< 200		
		3-03	1230	5	4,900	2,200	< 200		
		3-04			7,900	800	< 200		
		3-05			7,000	2,300	200		
		3-06	1200	8	160,900	54,200	17,200		
		3-07	1130	4.5	221,000	70,000	9,000		
3-03	3-08	3-08	1320	6	160,900	54,200	4,600	+	S. typhimurium var. copenhagen
		3-09	1215	6	34,800	24,000			
		3-10	1045	7		2,200			
3-06	3-11	3-11						-	
3-07	3-12	3-12	1130	9				-	
3-08	3-13	3-13	1240	9.5	24,000	1,100	500	+	
					Station 7 - Bolling Air Force Base, Buoy 9				
		3-03	1014	2	800	500	< 200		
		3-04	1015	2	800	< 200	< 200		
		3-05	1005	4	800	800	< 200		
		3-06	1010	4.5	700	130	80		
		3-07	1025	4.5	5,420	790	1,090		
3-03	3-08	3-08	0945	3.5	34,800	4,600	1,200	+	
3-04	3-09	3-09	1020	5	10,900	3,480		-	
3-05	3-10	3-10	0945	5.5		1,720		-	
3-06	3-11	3-11						-	
3-07	3-12	3-12						+	S. heidelberg
		3-13			3,450	240	460		
					Bellevue - "Fld" 23 Bell - 9.9 miles from Station 2				
		1-24	0840		70,000	31,000	200		
		1-30	1500	4	24,000	4,900	4,900		
		1-31	1325	5	240,000	79,000	2,300		
					Station 8 - Blue Plains, Buoy 8				
								+	S. newport
1-11	1-12							+	S. typhimurium var. copenhagen
								+	
1-11	1-16								
					Station 9 - Alexandria Marine Dock				
								+	S. derby
1-20	1-24							+	S. infantis

TABLE 2 - continued

Date Swab Set	Date Swab Retrieved	Date Sample Taken	Time Sample Taken	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Streptococci MPN/100 ml	Salmonella Recovery	Salmonella Serotype
					Station 10 - Woodrow Wilson Bridge				
1-11	1-16							+	S. typhimurium var. copenhagen
								+	S. montevideo
		1-24	0850		34,800	17,200	500		
		1-30	1445	4.5	91,800	34,800	7,600		
		1-31	1305	5	24,000	13,000	800		
		2-15	1015		1,609,000	220,000	10,900		
		2-16	0940		210,000	141,000	4,900		
		2-23	1300		31,000	11,000	800		
-	3-01							-	
		3-02	1215	2	175,000	94,000	10,900		
		3-03	1145	3	1,609,000	1,609,000	2,300		
		3-04			320,000	240,000	8,000		
		3-05			141,000	79,200	4,000		
-	3-06	3-06	1050	5	260,000	34,000	5,000	+	S. albany
		3-07	1035	4.5	58,000	11,000	< 2,000		
3-03	3-08	3-08	1130	5	13,000	< 2,000	8,000	+	
3-04	3-09	3-09	1130	6	7,000	2,000		+	
3-05	3-10	3-10	1000	6		2,300		-	
3-06	3-11	3-11						-	
3-07	3-12	3-12	1045	8				+	S. manhattan
3-08	3-13	3-13	1130	8.5	8,200	1,100	500	+	
					Station 11 - Broad Creek, Buoy 86				
		1-24	0905		13,000	4,900	700		
		1-31	1250	5	49,000	14,000	800		
		3-03	1100	3	542,000	172,000	3,300		
		3-04	1040	3	542,000	31,000	7,900		
		3-05	1030	4	91,800	91,800	2,400		
		3-06	1045	4.5	240,000	91,800	54,200		
		3-07	1110	4.5	34,800	13,000	4,900		
3-03	3-08	3-08	1020	4	54,200	24,000	4,900	+	S. montevideo
3-05	3-10	3-10	1010	5.5		4,900		-	
3-06	3-11	3-11						-	
3-07	3-12	3-12						-	
		3-13			34,800	7,900	3,300		
					Piscataway Creek F1 - 18.2 miles from Station 2				
		1-24	0920		3,300	2,300	< 200		
		1-31	1225	5	24,000	3,300	500		
					Station 12 - Fort Washington bank				
1-26	1-31							+	S. typhimurium
2-09	2-14							+	
2-14	2-20							+	S. give
2-20	2-24							-	

TABLE 2 - continued

Date Swab Set	Date Swab Retrieved	Date Sample Taken	Time Sample Taken	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Streptococci MPN/100 ml	Salmonella Recovery	Salmonella Serotype
					Station 13 - Fort Washington, Buoy 75				
		3-04	1130	3	160,900	24,800	800		
		3-04	1100	3.5	160,900	54,200	4,900		
		3-05	1045	3.5	160,900	54,200	1,700		
		3-06	1105	4.5	240,000	13,000	700		
		3-07	1135	5	34,800	2,300	3,300		
3-03	3-08	3-08	1050	4.5	34,800	4,900	4,900	+	S. bredeney
3-05	3-10	3-10	1030	5.5		10,900		+	S. montevideo
3-06	3-11	3-11						-	
3-07	3-12	3-12						+	S. tennessee
		3-13			63,000	2,500	1,400		
					Station 14 - Marshall Hall dock				
1-30	1-31							-	
2-03	2-04							+	S. montevideo
2-04	2-05							-	
					Station 15 - Dogue Creek, Buoy 67				
		1-24	0935		1,300	800	< 200		
		1-31	1145	5	13,000	1,300	200		
		3-03	1140	3	160,900	54,200	4,900		
		3-04	1110	3	160,900	7,000	500		
		3-05	1100	3.5	54,200	24,000	800		
		3-06	1120	4.5	160,900	4,900	500		
		3-07	1205	5	24,000	3,300	2,300		
3-03	3-08	3-08	1110	3.8	91,800	1,700	4,900	+	S. eimsbuettel
3-05	3-10	3-10	1050	7		7,000		+	S. montevideo
3-06	3-11	3-11						-	
3-07	3-12	3-12						-	
		3-13			63,000	11,000	900		
					Station 16 - Hallowing Point, Buoy 61				
		1-24	0950		1,300	500	< 200		
		1-31	1120	5	1,300	110	< 20		
		3-03	1205	3	3,480	700	< 20		
		3-04	1130	3	16,090	700	< 20		
		3-05	1115	2.5	16,090	5,420	50		
		3-06	1135	4.5	2,400	340	20		
		3-07	1235	5	10,900	5,420	< 20		
3-03	3-08	3-08	1125	4.5	34,800	7,000	9,180	+	S. give
3-05	3-10	3-10	1115	7		3,480		+	S. newport
3-06	3-11	3-11						-	
3-07	3-12	3-12						+	S. heidelberg
		3-13			34,000	170	790		

TABLE 2 - continued

Date Swab Set	Date Swab Retrieved	Date Sample Taken	Time Sample Taken	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Streptococci MPN/100 ml	Salmonella Recovery	Salmonella Serotype
					Station 17 - Indian Head dock				
1-30	1-24							+	S. alachua
1-26	1-31							-	
1-31	2-06							+	S. montevideo
2-09	2-14							-	
2-14	2-20							-	
2-20	2-24							+	S. panama
					Station 18 - Indian Head, Buoy 5A				
		1-24	1005		500	200	< 200		
		1-31	1100	5	700	110	< 20		
		2-03	1230	2.5	3,480	2,400	40		
		2-04	1150	3	9,180	700	20		
		2-05	1130	2.5	9,180	1,720	50		
		2-06	1150	4.5	9,180	210	< 20		
2-03	2-08	2-08	1200	4	91,800	24,000	3,480	+	S. give
2-05	2-10	2-10	1140	6.5		5,120		-	
2-06	2-11	2-11						-	
2-07	2-13	2-12						-	
		2-13			3,480	330	2,21.		
					Station 19 - Moss Point bank				
2-23	2-27							-	
-	3-02							+ + +	S. senftenberg
					Station 20 - Possum Point, Buoy 4A				
		2-23	1300	4	790	70	< 20		
		2-24	1705	2	20	< 20	< 20		
		2-27	1150		1,090	460	< 20		
		2-28		4	170	< 20	< 20		
		3-02	1330	3	700	130	< 20		
		3-03	1235	6	490	< 20	< 20		
		3-04	1205	4.5			< 20		
		3-05	1230	3	1,720	170	< 20		
		3-06	1325	3.5	490	40	< 20		
		3-08	1230	5	40	< 20	< 20		
		3-09	1300	5	16,090	2,400			
3-05	3-10	3-10		6		490		-	S. senftenberg
3-06	3-11	3-11						-	
		3-12	1205	?					
3-08	3-13	3-13			16,090	2,400	1,090	-	
3-09	3-14							-	

TABLE 2 - continued

Date Swab Set	Date Swab Retrieved	Date Sample Taken	Time Sample Taken	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Streptococci MPN/100 ml	Salmonella Recovery	Salmonella Serotype
					Station 21 - Sandy Point, Buoy 40				
		3-05	1215	4	130	20	< 20		
		3-06	1245	4	50	< 20	< 20		
		3-08	1200	4	170	20	< 20		
		3-09	1220	5					
3-05	3-10	3-10	1125	5.5		1,720		-	
3-06	3-11	3-11				9,180		-	
		3-12	1135	6.5					
3-08	3-13	3-13			5,420	330	1,300	-	
3-09	3-14							-	
					Station 22 - Smith Point, Buoy 30				
		2-23	1170	4	80	20	< 20		
		2-24	1105	3	20	< 20	< 20		
		2-27	1100	2	220	< 20	< 20		
		2-28	1230	4	< 20	< 20	< 20		
		3-02	1230	3	110	< 20	< 20		
		3-03	1700	4.5	80	< 20	< 20		
		3-04	1120		20	< 20	< 20		
-	3-05	3-05	1130	3	< 20	< 20	< 20	-	
		3-06	1215	4	50	50	< 20		
		3-08	1145	4	700	230	20		
3-04	3-09	3-09	1135	5	16,090	3,480		-	
3-05	3-10	3-10	1100	5.5		790		-	
		3-11							
		3-12	1100	6.2					
3-08	3-13	3-13			2,400	490	490	-	
3-09	3-14							-	
					Station 23 - Maryland Point Bank				
2-23	2-27							-	
-	3-02							-	
					Station 24 - Maryland Point, Buoy 19				
		2-23	1045	4	20	< 20	< 20		
		2-24	1035	3	< 20	< 20	< 20		
		2-27	1025	1	20	< 20	< 20		
		3-02	1150	3	< 20	< 20	< 20		
		3-03	1125	4	330	< 20	< 20		
		3-04	1040	5.5	50	< 20	< 20		
		3-05	1045	4	20	< 20	< 20		
		3-06	1140	3.5	< 20	< 20	< 20		
		3-07	1055	4	20	20	< 20		
		3-08	1110	3.5	2,400	330	< 30		
		3-09	1050	5	16,090	490			
3-05	3-10	3-10	1030	5.5		1,300		-	
3-06	3-11	3-11						-	
3-07	3-12	3-12						-	
		3-13	1025	6.5	16,090	230	700		

TABLE 2 - continued

Date Boat Set	Date Grab Retrieved	Date Sample Taken	Time Sample Taken	Water Temp °C	Coliform MPN/10[illegible] l	Fecal Coliform MPN/100 ml	Fecal Streptococci MPN/100 ml	Salmonella Recovery	Salmonella Serotype
					Station 26 - Nanjemoy Creek dock				
1-10	1-11							-	
1-11	1-06							-	
					Station 6 - Nanjemoy Creek, Buoy 11				
		-[illegible]	0915	[illegible]	< 20	< 20	< 20		
		-4	930	[illegible]	< 20	< 20	< 20		
		-5		[illegible]	< 20	< 20	< 20		
		-6	1050	[illegible]	< 20	< 20	< 20		
		-10	1000	[illegible]	< 20	< 20	< 20		
		-06	1000	[illegible]	< 20	< 20	20		
		-07	1000	[illegible]	< 20	< 20	< 20		
		-08	1040	[illegible]	16,090	5,420	700		
		-09	1010	[illegible]	240	50			
		-11		[illegible]		2,400			
1-10	-11	-11						-	
1-08	-13	-13			2,400	60	790	-	
1-09	-14							-	
					Station 27 - Aqualand seawall				
1-10	1-01							-	
1-11	1-06							-	
1-09	1-14							-	
1-14	2-10							-	
					Station 28 - Cobb Island bank				
1-09	1-14							-	
1-14	2-10							-	
					Station A - Blue Plains Sewage Treatment Plant				
		1-07	1415		16,090,000	5,420,000	348,000		
		1-08	1250		16,090,000	5,420,000	172,000		
		1-13	1145		9,180,000	790,000	230,000		
-	1-13	1-13	1500		17,200,000	700,000	220,000	+	S. infantis
		1-14	1325		5,420,000	700,000	140,000		
-	1-14	1-14	1540		17,200,000	2,300,000	220,000	+	S. cubana
		1-15	0915		34,800,000	10,900,000	4,600,000		
		1-15	1225		17,200,000	4,600,000	330,000		
		1-17	1150		54,000,000	1,100,000	330,000		
		1-17	1415		5,420,000	330,000	500,000		
		1-20	1250		17,200,000	1,090,000	260,000		
		1-21	1210		17,200,000	20,000	130,000		
		1-21	1450		5,420,000	40,000	330,000		

TABLE 2 - continued

Date Sent Set	Date Sent Retrieved	Date Sample Taken	Time Sample Taken	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Streptococci MPN/100 ml	Salmonella Recovery	Salmonella Serotype
					Station B - Arlington Sewage Treatment Plant				
		2-08	1140		5,400,000	790,000	918,000		
		2-09	1020		3,480,000	1,300,000	330,000		
		2-10	1310		5,420,000	1,300,000	490,000		
		2-10	1340		24,000,000	5,420,000	278,000		
		2-10	1450		16,090,000	16,090,000	542,000		
		2-13	1015		5,420,000	2,400,000	490,000		
-	2-13	2-13	1330		2,400,000	2,400,000	140,000	-	
		2-14	1200		3,480,000	700,000	1,090,000		
-	2-14	2-14	1415		9,400,000	2,100,000	790,000	+	S. cubana
		2-15	1020		3,480,000	2,400,000	490,000		
		2-15	1310		3,480,000	3,480,000	700,000		
		2-17	1035		2,400,000	490,000	790,000		
		2-17	1300		16,090,000	630,000	500,000		
		2-20	1130		3,480,000	1,090,000	1,400,000		
		2-21	1050		9,180,000	110,000	490,000		
		2-21	1330		24,000,000	210,000	700,000		
					Station C - Alexandria Sewage Treatment Plant				
		2-08	1215		5,420,000	490,000	175,000		
		2-09	1050		1,720,000	110,000	330,000		
		2-10	1345		9,180,000	5,420,000	700,000		
		2-10	1410		16,090,000	3,480,000	918,000		
		2-10	1505		17,000,000	2,400,000	542,000		
		2-13	1040		10,900,000	700,000	110,000		
-	2-13	2-13	1400		16,090,000	1,720,000	130,000	+	S. newington
		2-14	1230		16,090,000	460,000	80,000		
-	2-14	2-14	1445		10,900,000	800,000	230,000	+	S. muenchen
		2-15	1050		16,090,000	9,180,000	230,000		
		2-15	1340		9,180,000	3,480,000	490,000		
		2-17	1105		7,000,000	1,700,000	80,000		
		2-17	1330		5,420,000	330,000	230,000		
		2-20	1200		3,480,000	460,000	1,090,000		
		2-21	1125		5,420,000	50,000	130,000		
		2-21	1400		9,180,000	40,000	490,000		

TABLE 2 - continued

Date Swab Set	Date Swab Retrieved	Date Sample Taken	Time Sample Taken	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Fecal Streptococci MPN/100 ml	Salmonella Recovery	Salmonella Serotype
					Station 3 - Fairfax Westgate Sewage Treatment Plant				
		-02	1330		700,000	49,000	110,000		
		-03	1130		< 2,000	< 2,000	< 2,000		
		-04	1400		< 2,000	< 2,000	< 2,000		
		-13	1110		< 20,000	< 20,000	< 20,000		
-	0-13	-13	1430		< 20,000	< 20,000	< 20,000	-	
		-14	1450		< 20,000	< 20,000	< 20,000		
-	0-14	-14	1510		< 20,000	< 20,000	< 20,000	-	
		-15	1115		500	< 200	< 200		
		-16	1400		< 200	< 200	< 200		
		-17	1130		330	< 20	< 20		
		-17	1350		170	50	< 20		
		-20	1345		790	< 20	< 20		
		-21	1145		50	< 20	40		
		-21	1430		20	< 20	50		

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DISCUSSION

Indicator Bacteria in the Potomac Estuary

The 14-fold increase in fresh water flow of the Potomac River during the study slightly increased the bacterial densities of coliforms, fecal coliforms and fecal streptococci coming into the estuary from the upper basin. These same flow conditions, however, dramatically decreased the relatively large bacterial populations found in the metropolitan reach between the confluence with the Anacostia River down to Hallowing Point, apparently by flushing and diluting action. The lower reaches of the estuary, at least to the downstream limit of this study, were contaminated by this excursion.

Using a fecal coliform standard of 240 MPN/100 ml for water contact recreation, the Potomac Estuary from Chain Bridge to Indian Head would be unacceptable, and under some conditions, for the length of estuary investigated.

The distribution of the indicator species followed established patterns, i.e., coliforms most prevalent, fecal coliforms approximately a decimal order of magnitude lower, and a much more restricted distribution of fecal streptococci. The lesser numbers of the latter two are probably due in part to a lack of aftergrowth as suggested by Evan, *et al*. [3].

Some experimental findings by other investigators indicate there may be a significance in the fecal coliform/fecal streptococci ratio (FC/FS). Geldreich [5, 6] postulated that a ratio of less than 0.7 indicates animal pollution and/or urban stormwater discharges with higher ratios presumably due to human sources.

Examination of the FC/FS ratios as presented in Table 3 indicates: (1) a much wider fluctuation of ratios in the river than in the sewage treatment plants, (2) the magnitude of the ratios in the three treatment plants tended to fluctuate together, indicating a common cause such as infiltration, and (3) a dramatic general decrease in the magnitude of the ratio in the estuary after March 5, when the river flows rose. The interpretation of the fluctuations in the treatment plant data is confounded in that the precipitation was in the form of snow, with thawing temperatures during the days and freezing at night. Runoff patterns as well as infiltration rates into sewage systems are difficult to establish under these conditions.

The data, assuming the FC/FS ratio is valid, indicate the major source of pollution was from human sources in the estuary during the period from February 15 through March 5, 1967. Even with a 14-fold dilution effect, as the result of the increased runoff, the ratio still indicates the source to be substantially of human origin.

Table 3

FECAL COLIFORM/FECAL STREPTOCCI RATIOS

Potomac Estuary

February - March 1967

Stations	2/15	2/16	2/23	3/2	3/3	3/4	3/5	3/6	3/7	3/8	3/9	3/13
Chain Bridge	8.5	11.5	2.4					7.2	0.72	0.86		0.40
Key Bridge	24.5	26.0										
Memorial Bridge			1.1						1.6	1.9	1.0	2.0
Rock Creek - M Street				16.5	36.7	7.0	1.2	3.7	0.18	11.5		
Bolling AFB								1.6	0.72	3.8		0.52
Wilson Bridge	20.2	28.8	13.8	8.6	700	30	19.8	6.8				2.2
Broad Creek					52.1	3.9	38.2	1.7	2.6	4.9		2.4
Fort Washington					43.5	11.1	31.9	18.6	0.70	1.0		1.8
Dogue Creek					11.1	14.0	30.0	9.8	1.4	0.35		12.2
Hallowing Point							108.4	17.0	0.76			0.22
Indian Head					60.0	35.0	34.4			6.9		0.15
Possum Point								2.0				2.2
Sandy Point												0.25
Smith Point												1.0
Maryland Point												0.33
Marlboro										7.7		0.08

Table 3 (Cont.)

FECAL COLIFORM/FECAL STREPTOCCI RATIOS

Potomac Estuary

February - March 1967

Treatment Plants	2/2	2/3	2/6	2/13	2/14	2/15	2/17	2/20	2/21
Blue Plains	15.6		31.5	3.4/3.2	5.0/10.5	2.4/13.9	3.3/0.66	4.2	0.15/0.12
Arlington	0.86	3.9/2.6	19.5/29.7	4.9/17.1	0.64/2.7	4.9/5.0	0.62/1.3	0.78	0.22/0.30
Alexandria	2.8	0.33/7.7	3.8/4.4	6.4/13.2	5.8/35	39.9/7.1	21.2/1.4	0.42	0.38/0.08

Distribution of Salmonellae

Salmonellae were recovered from areas of the Potomac Estuary with chronically high coliform, fecal coliform and fecal streptococci, but not from areas where these bacterial densities were generally at acceptable levels under the environmental conditions during this study.

The Salmonella data cannot be compared with the indicator bacteria on a sound statistical basis because of their paucity and their non-parametric nature. It is instructive, however, to compare the percent of times Salmonellae were recovered with the densities of indicator organisms. Figure 7 shows the relationships found. At coliform densities less than 700 MPN 100 ml, fecal coliforms at 100 MPN/100 ml, and fecal streptococci at 20 MPN/100 ml, no Salmonellae were recovered. The greater incidence of Salmonella recovery was generally at higher indicator bacteria densities.

The incidence of Salmonellae in the Potomac Estuary confirms the usefulness of coliforms and fecal coliforms as indicators of bacterial pollution. Moreover, the high incidence of Salmonellae in waters with high bacterial densities of coliforms and fecal coliforms make the numerical indices used in water quality standards more realistic. This is contrary to some studies on fresh water rivers as reported by Gallagher and Spino [4].

All of the isolates sent to the U.S. Public Health Service Communicable Disease Center for sero-typing proved to be Salmonella

species. No apparent relationships existed between the species of Calanella and the distribution in the estuary, but the data are insufficient to draw sound conclusions.

INDICATOR - BACTERIAL DENSITY
and
SALMONELLA RECOVERY
UPPER POTOMAC ESTUARY
FEBRUARY - MARCH 1967
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

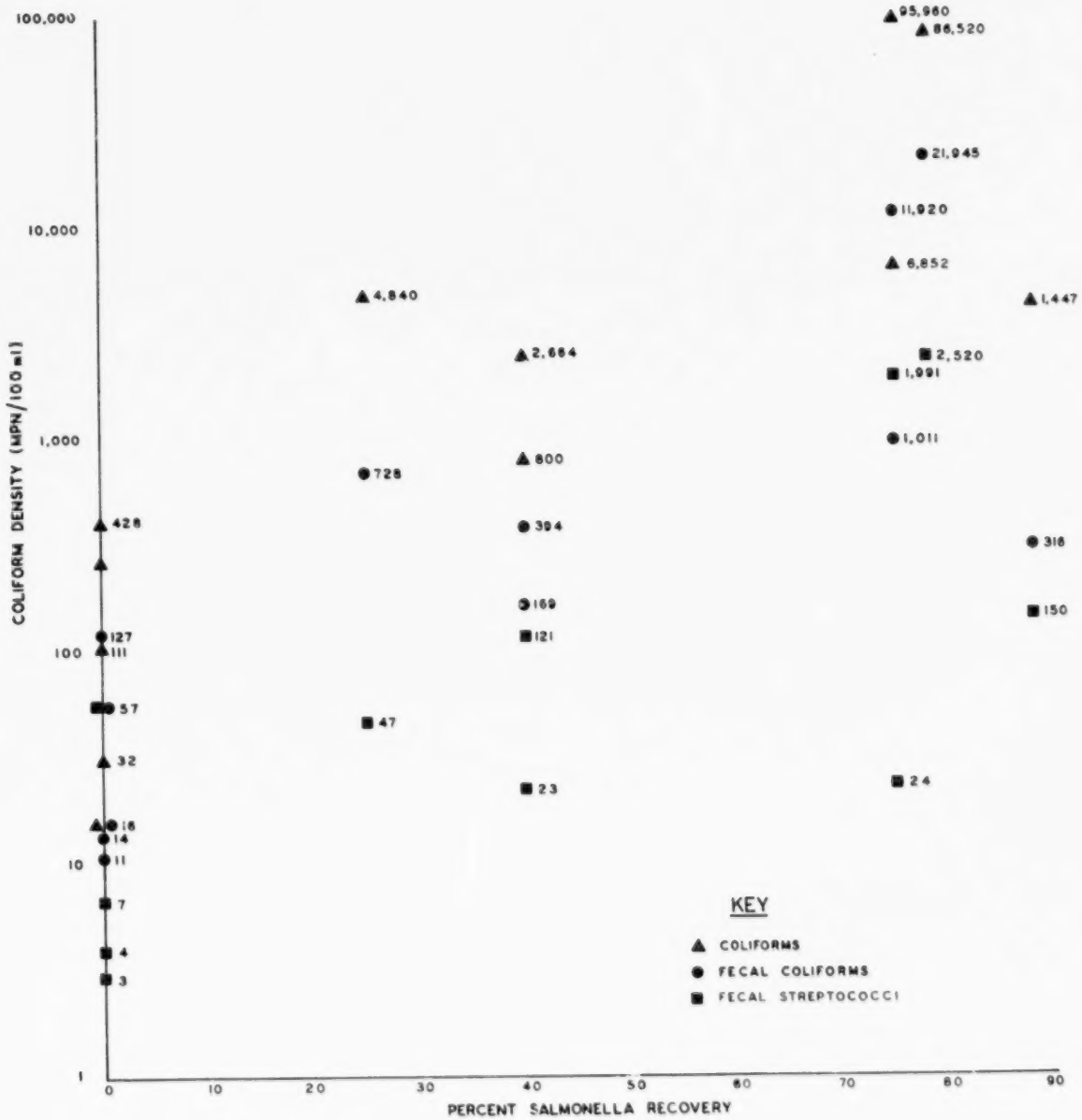

FIGURE 7

SUMMARY

The findings of the sanitary bacteriological survey of the upper Potomac Estuary during January-March of 1967, are summarized below:

1. High coliform, fecal coliform and fecal streptococci densities were found in the Washington metropolitan area.

2. A potential health hazard existed in the Washington metropolitan area, with Salmonella organisms readily and regularly isolated.

3. Three of the four major sewage treatment plants in the Washington metropolitan area contributed large volumes of indicator bacteria as well as Salmonellae, to the upper Potomac Estuary.

4. A rapid rise in river flows during the study had a two-fold effect on water quality by (a) considerably reducing by dilution the bacterial densities in the upper estuary near the waste-water discharges, and (b) increasing the bacterial densities in the middle estuary by flushing indicator organisms downstream a distance of at least 50 miles.

5. Fecal coliform/fecal streptococci ratios indicated that the bacterial pollution in the upper Potomac Estuary was probably of human origin.

6. In general, greater incidence of Salmonella recovery was obtained in waters having high indicator-bacterial densities.

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